CellPress

Feature

Counting carbon costs

Ahead of the 24th annual global summit on climate change, science provides ever more detailed and reliable scenarios of the catastrophic damage that the ongoing man-made climate change is going to cause in the years to come. However, people with the power to do something about it still don't take much notice, and denialists even win elections. **Michael Gross** reports.

On Monday October 15th, the UK government launched its very first 'Green Week' to boast about its successes in reducing carbon emission: "Clean growth is a true British success story." Unfortunately, the government forgot to mention that much of the reduction is due to manufacturing comprehensively relocating to Asia and emitting its carbon dioxide there, while the business growth is in insecure service jobs.

Still, this exercise in 'greenwashing' might have passed unnoticed in the general political chaos surrounding the Brexit crisis. It was just a rather unfortunate coincidence that, on the very same day, the energy company Cuadrilla started operations at its first hydraulic fracturing (fracking) site in the UK since a previous attempt was abandoned seven years ago (Curr. Biol. (2013) *23*, R901–R904). After fierce protests and extended legal battles, the company meant to start working at Preston New Road, Lancashire, on Saturday 13th, but was held back by storm Callum. Protesters, undeterred by the draconian prison sentences handed out in September to three men who had done nothing but climb on top of a lorry, were out in force. (Those sentences were overturned by a court of appeal on October 17th.)

Thus, if energy minister Claire Perry made the effort to check social media on that Monday to admire the impact of her 'Green Week', she will have found heaps of reports of fracking protests, and remarks on the irony of having a week dedicated to environmental concerns starting with the onset of yet more fossil fuel production.

Elsewhere, around the world, protesters have a busy schedule as politicians keep making decisions favouring environmentally unsustainable business over the need to avert catastrophic climate change. Many of them keep moving things in the wrong direction regardless of science providing ever more detailed and dire predictions on how climate change will affect all of us, including the unrepentant polluters.

Social cost of carbon

One of the economic approaches considered to tackle climate change is to raise taxes on carbon emissions. This serves to ensure the unseen damage that the carbon emission causes becomes part of the emitter's balance sheet. Economists speak of converting an externality (not part of the balance) into an internality that does affect the bottom line.

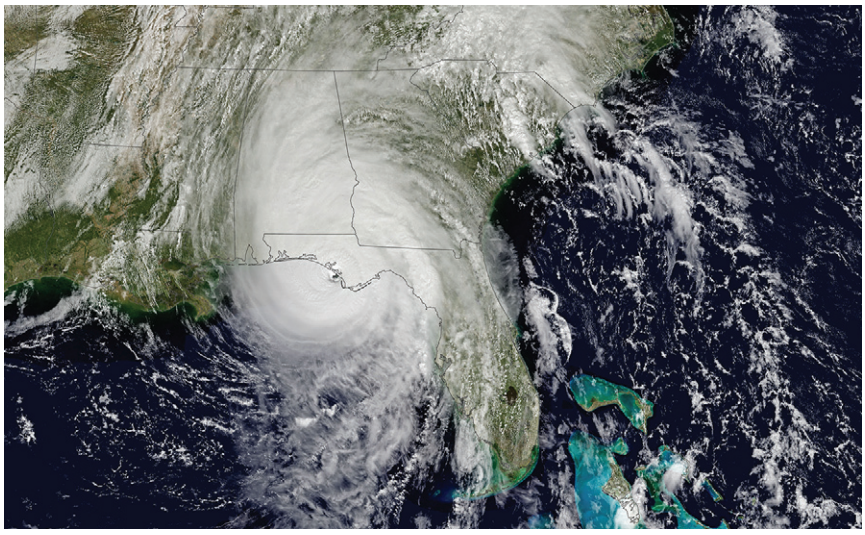
But how much damage does a tonne of carbon dioxide provoke? Existing carbon taxes value it between 10 and 20 US dollars, but most scientific estimates are substantially higher, with a range from $10 to $1,000.

In the most detailed study of the social cost of carbon so far, Katharine Ricke from the University of California at San Diego, USA, and colleagues estimate both the global cost of carbon emissions and the share of this overall burden to fall on each country (Nature Clim. Change (2018) *8*, 895–900). The median of their estimates on the global scale is $417 per tonne of carbon emitted, suggesting that carbon taxes are too low by more than an order of magnitude.

This social cost is spread very unevenly around the globe, however. Some countries may even stand to benefit from warming, and are thus accounted for with a negative contribution to the overall cost. This is the case especially for countries at high latitudes like Canada and Russia, where a temperature increase would help the productivity of agriculture and reduce the costs of extreme winter weather.

Ricke and colleagues warn, however, that these benefits could prove short-lived, as the calculations of these country-specific values don't take into account damage happening elsewhere, which may cause economic crises, mass migration and possibly armed conflicts, and thereby produce knock-on effects on the countries that have initially benefited from warming. In the long term, the authors predict, the costs will outweigh benefits in most if not all countries.

The highest share of the economic damage falls upon some of the biggest emitters of carbon dioxide.



Storm surge: The United States is among the countries bearing the highest costs from climate change, including the increasing damage from tropical storms like the recent Hurricane Michael, shown here approaching Florida. (Photo: NASA Earth Observatory image by Joshua Stevens, using data from GOES-16.)

On the edge: Climate change protesters at Hambacher Forst, Germany, where an open cast mining operation for lignite is destroying ancient woodlands and several villages. (Photo: Leonhard Lenz.)

Across several different analyses, the United States, China and India appear among the countries suffering the biggest impacts. When all analyses are merged into a single figure for each country, India comes out carrying the largest economic burden, at $86 per tonne of carbon dioxide added to the atmosphere anywhere, or 21% of the global cost. It is followed by the United States ($48), Saudi Arabia ($47), Brazil and China (both $24).

These figures show very dramatically which countries are most forcefully hurting their own economic interests by not being more proactive in converting to sustainable technology. The United States, for instance, is already experiencing the damage wrought by the increasingly vehement hurricanes fuelled by warmer surface water in the Caribbean — a connection that climate attribution science can already confirm with confidence (Curr. Biol. (2017) *27*, R1249–R1252).

However, it is worth remembering that the country figures reported by Ricke and colleagues are only representing a small part of the overall damage caused. Thus, the authors note, if each country mistakenly took this figure as a standard to set its carbon tax, only 5% of the global social cost would be internalised, and the 1.5°C target of the Paris agreement could not be met.

Difference by degrees

On October 8th, the Intergovernmental Panel on Climate Change (IPCC) released a special report spelling out the ways in which a global temperature increase of 1.5°C would yield benefits in comparison to a 2.0°C warming or the more catastrophic 3.0°C that would be the result of staying on the current trajectory (http://ipcc.ch/report/sr15/).

The report estimates the warming that has already occurred since pre-industrial times amounts to 1.0°C (± 0.2°C), and projects that the threshold of 1.5°C will be reached between 2030 and 2052 if warming is allowed to continue at its current rate. The emissions released to date are set to disrupt the Earth systems for decades to come, the report notes. However, without any further carbon dioxide emissions in excess of the capacity of the natural carbon cycle, the carbon already released would probably not cause heating to the 1.5°C threshold. Thus, the amounts of carbon released in the next decade will decide whether global temperatures will stay within that limit or whether they will overshoot it.

Earlier work had already shown that 4°C would spell global disaster (Curr. Biol. (2010) *20*, R1052–R1053), which is why 2°C became a widely used target in the climate summits from Copenhagen (2009) through to Paris (2015). The IPCC report now calls on decision-makers to be more ambitious and aim for 1.5°C instead, which is also mentioned in the Paris agreement as a preferable outcome. Although the world is essentially facing the choice between disasters of different magnitudes, the report manages to put a positive spin on the choice by using 2.0°C warming as a baseline and highlighting the benefits that would result from bringing the figure down to 1.5°C.

For instance, the meteorological and geophysical parameters, such as increase of temperature extremes, likelihood of extreme storms and rainfalls, sea-level rise, and ocean acidity, are all predicted to look more favourable in 1.5°C scenarios than at any higher temperatures. In terms of the impact on wildlife and human societies, the report also predicts that risks to health, livelihoods, food security, water supply, human security, and economic growth will increase less dramatically under the more moderate warming scenario.

None of these projections should come as a surprise to anybody, but the big question is whether any political or business leader will actually draw the necessary consequences to ensure the world stays within the relative safety of the 1.5°C boundary.

Changing direction

If anthropogenic warming is to be contained within this boundary, changes will be required to a wide range of industries, not just the energy and transport sectors, which are often in the focus of attention on sustainable technology and renewable energy use. More and more analyses give an ever more detailed picture of how anthropogenic change to environmental conditions adds up on the global scale and how its causes and effects are distributed between countries and regions.

A recent study analysing the global carbon footprint of tourism and the contributions of countries both as sources and as destinations of travel

described a rapidly growing industry still largely untroubled by controls and regulations of its climate impact (Curr. Biol. (2018) *28*, R963–R965).

This October, just days after the IPCC report, Marco Springman from the University of Oxford, UK, and colleagues published an assessment of the global food system (Nature (2018) https://doi.org/10.1038/s41586-018-0594-0) in terms of the planetary boundaries concept pioneered by Johan Rockström and colleagues (Curr. Biol. (2015) *25*, R131–R134).

Springman and colleagues project that between 2010 and 2050, due to changes in global population and wealth, the environmental impact of the food system may increase by 50–90%. This development will exceed planetary boundaries, including those for greenhouse gases as well as others such as the circulation of phosphorus and nitrogen.

As meat production — projected to increase further as the developing world gets wealthier — is a major contributor to climate change and other environmental problems (Curr. Biol. (2015) *25*, R965–R967), the authors conclude that diet change towards more plant-based nutrition will be necessary.

Information on the health and environmental implications of a meat-rich diet alone is unlikely to achieve a noticeable behaviour change, the authors concede. They call for multi-component policies, including incentives for farmers and infrastructure investments along with educational measures such as dietary guidelines, all of which will have to be designed on regional levels to take into account the specific geographical and cultural context.

Lost in the woods

But what if most of the 7.7 billion people on the planet stubbornly continue to embrace or aspire to the carbon-intensive lifestyle of the Western world, with its meat-rich diet and diesel-fuelled vehicles? Those looking for solutions that don't require a cutback to consumerism have set their hopes in forests.

The Paris agreement mentions sustainable forest management as a way to limit warming and mitigate the consequences of climate change. It sets out four criteria that sustainable, climate-friendly forest management should comply with. It should reduce the increase of atmospheric CO_2 concentrations and reduce the greenhouse effect of the atmosphere, while neither increasing air temperatures near the surface nor decreasing rainfall.

Climate culprits: Cattle make a significant contribution to anthropogenic greenhouse gas emissions. (Photo: Barney Moss, Flickr.)

Sebastiaan Luyssaert from the Vrije Universiteit Amsterdam, Netherlands, and colleagues have now shown that available strategies for managing forests in Europe can meet at most two of these four criteria (Nature (2018) *562,* 259–262). Thus, the authors conclude, trade-offs are unavoidable. Even the best forest management cannot avert the damage done by our carbon dioxide emissions. Any benefits from good forest management in Europe, the authors warn, will be significant only on the regional scale and negligible in terms of their impact on global change.

In a separate effort, researchers at the University of Birmingham, UK, exposed trees to the carbon dioxide concentrations that the Earth will experience from 2050 onwards. Working with Alan Jones from Earthwatch Europe, and using growth measurements taken by numerous volunteer helpers, they have shown that the rising carbon dioxide concentration in the air only boosts the carbon sequestration achieved by forests in the short term. After a few years, the experimental study found, the trees revert to baseline carbon sequestration. A metastudy of plant responses to high CO_2 concentrations has been published by Wenjuan Huang and colleagues (Sci. Rep. (2015) *5*, 18225).

These findings suggest that, while we obviously need what is left of the Earth's forests and their carbon sequestration activity, we cannot rely on them to bail us out when we overrun our carbon budget. Instead, politics and policy need to change, but will they?

System failure

In December, delegates will meet for the 24th annual 'conference of parties' to the UN convention of climate change at Katowice, Poland, which among other things highlights the fact that the global community has now spent a quarter of a century talking about doing something to combat climate change, with very little success to show for it.

The Montreal protocol of 1987 which came into effect in 1989 has successfully phased out the release of chlorofluorocarbons into the atmosphere and thereby saved humanity from catastrophic damage to the stratospheric ozone layer. Although climate change is similar in that it also involves the distribution of man-made gases in the global atmosphere, a similar success in this field has remained elusive.

Even what little has been achieved in terms of non-binding declarations of intent in the Paris agreement is under threat from populist political leaders who prefer to peddle simple answers that are simply wrong rather than engaging with the complex scientific truth (Curr. Biol. (2017) *27*, R1–R4).

Fog lifting: The 24th global climate summit (COP24) will take place in Katowice, Poland, in December. The city has historic importance in the steel industry and was transformed by modernist architecture in the 1970s. (Photo: Midnight Believer, Flickr.)

US president Donald Trump announced in August 2018 that his administration intends to pull out of the Paris agreement as soon as it is legally possible to do so. This will be the case in November 2019, three years after the agreement came into force in the US.

Later in August, the then Australian prime minister Malcolm Turnbull backtracked from a green energy plan that would have helped Australia to meet its commitments under the Paris agreement. This U-turn was forced by his predecessor, Tony Abbot, who, ironically, had been the prime minister signing the Paris agreement for Australia. It failed to save Turnbull's position, however. He was replaced by Scott Morrison, who is known as a defender of Australia's coal exports and hasn't presented any discernible climate policy yet.

Meanwhile, Germany hasn't quite got round to abandoning the open-cast mining of brown coal (lignite), which is regarded as an especially polluting type of fossil fuel and devastates entire landscapes. Protesters motivated by climate change concerns have occupied the forest of Hambacher Forst near Cologne for years now in a bid to stop its destruction. The legal and physical battle continues. Similar fights are also likely to reignite in England, as the production of shale gas by fracking resumes.

Quite possibly the biggest impact on climate and environmental policy could arise from the presidential election in Brazil, however, which goes into its decisive round on October 28th, as this article is in press. The far-right candidate Jair Bolsonaro, who was ahead in the first round with 46% of the votes, has already announced he will withdraw from the Paris agreement, weaken environmental regulations, close the ministries for science and the environment, and cut the federal science budget. Considering the size and global importance of the remaining Amazon rainforest, Bolsonaro's election could herald a global environmental disaster of unimaginable extent.

Democracies are said to be more successful than autocratic regimes because the checks and balances and frequent changes of leadership ward off the dangers of extreme decisions. That remained true until the combination of populism and turbo-charged communications technology produced a situation where pied pipers can lead entire nations over a cliff and the truths of science are no longer heard. Which is why, even after a quarter of a century of discussions, the Katowice summit does not have much of a chance to stop climate change.

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Book review

Profound rumblings from the bowels of the lobster

John C. Tuthill[1]

Lessons from the Lobster: Eve Marder's Work in Neuroscience
Charlotte Nassim
(The MIT Press, Cambridge, MA; 2018)
ISBN: 978-0-262-03778-5

In his essay 'Consider the Lobster', David Foster Wallace summed up the tepid state of human–lobster relations: "for practical purposes, everyone knows what a lobster is. As usual, though, there's much more to know than most of us care about — it's all a matter of what your interests are."

For the last 40 years, the part of the lobster that has most interested Eve Marder is its stomach, specifically a cluster of approximately 30 neurons known as the stomatogastric ganglion, or STG. Neurons in the STG are organized into two interconnected circuits: one controls a set of internal teeth that break down food particles, while the other dilates and constricts a tube that forces food into the animal's gut. In the Marder lab at Brandeis, electrophysiological studies of the neurons that control crustacean munching have transformed how we think about the flexibility, variability, and outright sloppiness of brains.

What would compel someone to study the neural circuits that control lobster mastication and swallowing? The reasons are too many to list exhaustively here, but here are just a few good ones. First, the STG is easy to work with because it produces rhythmic patterns of activity even when removed from the animal and pinned in a dish (as shown in the figure below). STG neurons are humongous: 50–100 μm in diameter (compare this with the measly 3–5 μm neurons in my own critter of choice, the fruit fly). They are also uniquely identifiable in each individual lobster, and even across crustacean species, so you can record from the same cell type day after day. Finally, if you study the STG, you may get the chance to work with Eve Marder, an undisputed sage and genie of neuroscience.